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METHOD FOR GASIFICATION OF A SOLID CARBONACEOUS FEED AND A REACTOR FOR USE IN SUCH A METHOD

The invention is directed to a method for gasification of a solid carboneous feed, wherein said gasification is performed in an elongated gasification reactor vessel comprising a gasifier unit, a co-axial positioned cooled channel through which the dust-loaded hot-gaseous product of the gasifier unit is discharged from the reactor, and means to supply a quench gas to the dust-loaded hot gaseous product at a position downstream of said gasifier unit.

Such a process is described in US-A-4859213. This publications describes a typical coal gasification process as performed in an elongated gasification reactor vessel comprising a gasifier unit, a co-axial positioned cooled channel through which the dust-loaded hot-gaseous product of the gasifier unit is discharged from the reactor, and means to supply a quench gas to the dust-loaded hot gaseous product at a position downstream of said gasifier unit. Pulverized coal from a coal feed system is fed into the gasifier unit via burners along with an oxygen containing gas. In the gasifier pulverized coal is partially oxidized with oxygen to a carbon monoxide-hydrogen comprising gas (syngas), further also referred to as product gas. Ash, in the form of slag, gravitates in the cooled channel into a slag bath tank located at the lower end of the elongated reactor. Product gas, containing dust and entrained liquid slag droplets, rises in the cooled channel to a quench section. The quenched product gas exits the gasification

reactor via a duct into a waste heat boiler or syngas cooler. Solids are removed from the resultant cooled product gas in a so-called solids removal section. A portion of cleaned and cooled gas from the solids removal section is then fed back, by means of a recycle gas compressor, into the cooled channel as quench gas. The quench gas entering the cooled channel cools the product gas such that entrained fly slag particles are solidified and will not stick to the duct or waste heat boiler surfaces as the solids and gas pass through.

In the carbon gasification process, as for example disclosed in US-A-4859213, a carboneous feed is transformed under high temperature and pressure into a hot product gas. Inert ash components contained in the carbon are partly discharged with the hot product gas stream from the gasification reactor in form of fine dust. Since the gasification pressures are up to 50 bar and higher, the components used in the gasification process, such as the gasification reactor, quench means, cooled channel, duct and the downstream heat exchanger heating surfaces, must be operated within a pressure wall which can be realized by one or more pressure containers or pressure mantles. To protect the pressure mantles of the reactor against the high syngas temperatures of over 1500 °C, the quench tube and the cooled channel are provided with water-cooled cooling surfaces. The dust-loaded hot product gas is cooled with cold quench gas supplied from a quench gas supply unit to a temperature of approx. 900 °C. A further cooling takes place in one or more heat exchanger surfaces downstream said quench unit whereby steam is produced.

Between the gasifier unit, the quench unit, and the cooled channel and the pressure wall of the gasification

reactor an annular space is created as is also shown in US-A-4859213.

The cooling surfaces of the cooled channel can only withstand small gas-side pressure differences. The pressure between the interior of the cooled channel and the annular space has therefore substantially to be compensated. Openings which fluidly connect the cooled channel and the annular space are for example sliding points in the wall of the cooled channel for compensating thermal expansions and the openings at the quench unit.

To this end it is known from the speech "Criteria for Design of Gasifier and Syngas Cooler" of Dr. G. Keintzel and Dipl.-Ing. Gawlowski, held at the conference EPOS 2000 - International Conferencce on Efficiency, Cost, Optimisation, Simulation and Environmental Aspects of Energy and Process Systems, July 5-7, 2000, University of Twente, Enschede, The Netherlands, Figure "Heating Surfaces in the Syngas Cooler", to make the sliding point associated with the cooled channel open or to provide it with gas-permeable plugs, in order to thereby achieve a pressure compensation at least at a hot-gas guiding channel segment separated from the pressure wall by gas barriers. Therefore, during pressure compensation dust-loaded hot- product gas enter the annular space. In a carbon gasification plant of industrial scale it has been found that an undesired flow on the gas side occurs in the annular space charged with gas, i.e. a so-called secondary flow, since the hot-gas can cool down at the side of the cooling surface oriented towards the annular space and at the pressure wall, and cooled gas can flow back via the sliding point into the cooled channel. In this way an undesired heating up of regions of the

respective pressure wall and setting of dust occurs. This can lead to operation failures.

It is an objective of the present to provide a gasification process as generally described above wherein dust loaded product gas cannot enter the annular space and therefore dust depositions are avoided.

The following process achieves this object. A method for gasification of a solid carbonaceous feed, wherein said gasification is performed in an elongated gasification reactor vessel comprising a gasifier unit, a co-axial positioned cooled channel through which the dust-loaded hot-gaseous product of the gasifier unit is discharged from the reactor, and means to supply a quench gas to the dust-loaded hot gaseous product at a position downstream of said gasifier unit, wherein to an annular space between the reactor vessel wall and the cooled channel a dust-free gas is supplied at a rate sufficient to ensure that no dust-loaded hot gas will flow from the cooled channel to said annular space.

Applicants have found that by supplying such a dust free gas to said annular space no dust loaded hot product gas will pass via the openings, such as at the cited sliding points and at the quench supply means, in the wall of the cooled channel. A so-called positive flow of dust-free gas will exist from the annular space into the cooled channel. To arrive at such a positive flow the rate of dust-free gas as supplied to said annular space is preferably such that the pressure in said annular space is at least equal or just higher than the pressure in said cooled channel. The above is also referred to as a method for pressure compensation.

Also here an inadmissible heating up of the pressure wall cannot take place since a secondary flow is

effectively suppressed. Therefore no substantial quantities of dust can settle in the annulus surrounding the heat exchanger heating surfaces.

While with the earlier proposed charging of the annulus with the dust-loaded hot gas the pressure within the annulus is kept somewhat lower than in the gas interior, the method of the invention intends to charge the annulus with the quench gas in such a way that the gas pressure within the annulus is equal to or somewhat higher than the gas pressure in the gasifier unit and channel.

The temperature of the dust-free gas is preferably between 200 and 350 °C and more preferably below 300 °C.

The dust-free gas is preferably part of the gaseous product of the gasifier unit from which dust has been removed downstream of said gasification reactor, for example the dust free product gas as obtained in the solids removal section. Because this dust-free product gas is also preferably used as quench gas it has been found advantageous to combine the supply of the dust-free gas to the annular space with the supply of quench gas to the cooled channel. In this preferred embodiment the means to supply quench gas is preferably provided with gas discharge openings to supply quench gas to the cooled channel and gas discharge openings to supply quench gas to the annular space. It has been found that by providing sufficient openings in said means to supply quench gas a robust and reliable operation is achieved. One skilled in the art will be able to easily determine the area of these openings given the pressure level of the quench gas and the pressure level in the cooled channel.

In a preferred embodiment any sliding points present in the cooled channel are rendered gas-tight with respect

to the hot-product gas guided in the cooled channel. With the method of the invention the pressure compensation function is separated from the function of the sliding point, since the quench gas used for pressure compensation is introduced from the quench unit between the gasification reactor and the quench tube into the annulus.

In this way the pressure compensation function is also separated from the other two functions attributable to the sliding point, i.e. is the expansion function and the assembling separation function. Preferably one or more gas barriers can be situated in the area of small differential expansions between the respective pressure wall and the respective cooled component so that the secondary function of compensating substantial differential expansions in the axial direction of the components at the sliding point is omitted.

Furthermore, it is useful that the annulus present in the syngas cooler, which is confined by the at least one heat exchanger surface and the pressure wall surrounding it and which is closed against the annulus charged with quench gas, is charged with cooled hot-gas.

The present invention is also directed to an elongated gasification reactor vessel, which may be used in the above described process, comprising a gasifier unit, a co-axial positioned cooled channel through which the dust-loaded hot-gaseous product of the gasifier unit is discharged from the reactor, and means to supply a quench gas to the dust-loaded hot gaseous product at a position downstream of said gasifier unit, wherein also means to supply a dust-free gas to an annular space between the reactor vessel wall and the cooled channel is present. Preferably the means to supply quench gas is

provided with gas discharge openings to supply the majority of the quench gas to the cooled channel and gas discharge openings to supply a minor amount of quench gas to the annular space. The means for supplying the quench gas are usually holes (exit openings), the size of which determining the quantity of gas passing to the quench tube and the annulus, respectively.

Preferably the cooled channel is provided with sliding points which are rendered gas-tight with respect to the hot-gas guided in the cooled channel.

Preferably, there is one or more sliding points in the cooled channel downstream of said quench gas supply unit. Such sliding points are present between two cooled channel segments and/or at the end of the cooled channel. Preferably an annular barrier for closing the annular space is situated downstream of said sliding points.

It is useful that a further sliding point is provided in the area of the connection path and this sliding point is preferably associated with an enlargement of the pressure mantle in order to be able to better use the function of the assembling separation in the area of the sliding point.

As said before, in known carbon gasification plants at least one heat exchanger heating surface surrounded by a pressure wall is connected downstream of the cooled channel in order to further cool down the gas (product gas). In this connection it is useful that a sliding point is provided between the cooled channel and the heat exchanger heating surface and that the annular barrier for closing the annulus downstream of the sliding point is situated upstream or downstream of the heat exchanger heating surface.

Usually several heating surfaces connected one after the other at the gas side are used, which are surrounded by the same pressure wall. Preferably, the pressure compensation takes place between the gas interior in the heat exchanger heating surfaces and the surrounding annulus with dust-loaded hot-gas previously cooled down in the heat exchanger heating surfaces. Due to the substantially lower temperatures as compared to the temperatures in the area of the hot-gas guiding channel secondary flows and hence massive dust settlement in the annulus cannot occur anymore.

In case of a plurality of heat exchanger heating surfaces it is useful to insert a gas-tight sliding point between at least two adjacent heating surfaces.

The invention will now be described in connection with the enclosed drawings. In the drawings:

Fig. 1 shows an embodiment of the carbon gasification plant wherein the gasifier unit is situated in a first pressure container (gasification reactor) and the heat exchanger heating surfaces are situated in a second pressure container (syngas cooler), wherein the two pressure containers are connected through a rising connection path (so-called duct); and

Fig. 2 shows a representation of a further embodiment comparable to Fig. 1, with an inclined connection path (duct).

The gasification plant depicted in Fig. 1 consists of a gasification reactor 1, a connection duct 2 and a syngas cooler 3. The gasification reactor 1 comprises a vertically oriented elongated pressure container 4 in which a cooled channel 5, 7 and a quench gas supply unit 6 are located. The gasifier unit 8 is supplied with a carboneous feed, for example pulverized coal. The

quench gas supply unit 6 is fed with quench gas Q at 9. Quenched hot-product gas HG flows in the cooled channel part 7 downstream the quench gas supply unit 6. The cooled channel is provided with cooling surfaces. Preferably these cooling surfaces are bundles of conduits through which cooling water flows. A preferred cooling surface is the membrane wall as disclosed in for example US-A-4859213.

The lower end of the gasification reactor 1 is provided with a gas barrier 10. Furthermore, slag S is discharged at the lower end 11 of the gasification reactor 1. The pressure container 4 consists of a lower part 4a and an upper part 4b with an angled flange 4c. The pressure mantle 12 connects thereto. The syngas cooler 3 comprises a pressure container 13 consisting of three container parts 13a, 13b, 13c. The pressure container part 13 comprises an angled flange 13d oriented downwards which defines, together with flange 4c and pressure mantle 12, the connection path 2. Within the gas cooler 3 there are e.g. three heat exchanger heating surfaces 14 situated one above the other, as seen in the direction of flow of the hot-gases HG. The heating surfaces are only shown schematically and can be e.g. in the form of heating surfaces with a cooled gas guiding mantle 14a and straight or winding tube interiors 14b. In the embodiment shown the gas guiding mantles 14a of the two upper heating surfaces are connected together to form a gas guiding mantle 15 which is connected to the gas guiding mantle 17 of the lower heating surface via a gas-tight sliding point 16.

The connection between the cooled channel part 7 and the gas guiding mantle 15 is made via a hot-gas guiding channel 18 which extends in a curved portion 18a into the

pressure container 4, in a straight portion 18b through the pressure mantle 12 and the flange 13d, and which is formed in its last portion as a gas deflection chamber 18c.

The gas-guiding channel 18 is provided at its entrance end with a sliding point 19, which allows a sliding movement relative to the quench tube 7, which is provided with an enlargement 7a at its exit end. This enlargement is schematically shown as a simple cone.

The opposing ends of cooled channel part 7 and gas guiding channel 18 are provided with compensator holders 20 and 21 between which a ring compensator 22 extends so that the sliding point 19 is gas-tight with respect to the hot hot-gas exiting from the quench tube. In the connection path 2 in the area of the pressure mantle 12 there is provided a further sliding point 23 between two portions S1 and S2 of the gas-guiding channel 18, the portion S1 having an enlargement at its exit end. The sliding point 23 corresponds in its design to the sliding point 19.

Between the exit end of the gas guiding channel 18 situated in the gas cooler 3 and the entrance to the gas guiding mantle 15 there is provided a further sliding point 24 which differs in design from the sliding points 19 and 23 in that the enlargement 15a, as seen in the direction of gas flow, is not disposed at the exit end of the gas guiding channel 18 but at the entrance end of the guiding mantle 15. The sliding point 15 corresponds in its design to the sliding point 24.

It is possible to dispose the enlargement for the sliding points 19 and 23 also at the other gas-guiding element. Equally, at the sliding points 16 and 24 the

enlargement can be provided at the downstream entrance end of the gas guiding section.

As shown in Fig. 1, the gasification reactor 5, the cooled channel part 7, the gas guiding channel 18, the gas guiding mantle 15 and the gas guiding mantle 17 are surrounded by an annulus 25 defined by the pressure container 4, the pressure mantle 12 and the pressure container 13. This annulus is confined on the one hand by the annular barrier 10 in the gasifier unit 1 and is subdivided by an annular barrier 26, which is situated between the sliding point 24 and the upper heating surface 14, into two partial annulus 25a and 25b.

Since the sliding points 19, 23, and 24 are gas-tight with respect to the dust-loaded hot-gases guided within the gas interior, in regular operation no dust-loaded hot-gas can enter the annulus 25a.

For pressure compensation between the gas interior of gasification reactor 1, cooled channel part 7, and gas guiding channel 18, the annulus 25a is charged with quench gas Q which exits via exit openings 27 from the quench gas supply unit 6 into the annulus 25a. The geometry of the exit openings 27 is selected in correspondence with the pressures such that the pressure in annulus 25a is equal to or somewhat higher than the gas pressure of the hot-gas in the gas interior. Since the quench gas enters the annulus with a substantially lower temperature (e.g. 250 °C) than the temperature of the hot-gases in the gas-guiding channel 18 (e.g. 900 °C) a critical heating up of the respective pressure walls cannot take place. Since the quench gas is free of dust, dust settlement cannot occur.

The annulus 25b downstream of the annular barrier 26 is charged backwards and upwards by the already partly

cooled down hot-gas exiting the lower end of the gas guiding mantle 17 which is cooled down e.g. to 300-250 °C.

Since the annulus 25b is charged with still dust-loaded but substantially cooler gas, secondary flows due to rising and subsequently cooling down hot-gas streams cannot occur.

As shown in Fig. 1 in broken lines the pressure mantle 12 can have an enlargement 12a, which allows entering the sliding point 23 via an entrance opening 12b for inspection purposes.

It is also possible to dispose the annular barrier 26 downstream of one of the heating surfaces 14 and thus to enlarge the annulus 25a. It is also conceivable to dispose the annular barrier 26 above the sliding point 24.

The embodiment of Fig. 2 differs from the embodiment of Fig. 1 in that the connection path between the gasifier 1 and the gas cooler 3 is not rising, but falling. The two general designs according to Figs. 1 and 2 with rising or falling connection path 12 are also known from the Figs. 1 and 2 of US-A-4859214. Also in the embodiment of Fig. 2 an enlargement 12a can be provided for. Other connection paths are also possible, for instance horizontal or curved paths.

Thus, in both embodiments the annulus 25 confined between the components and the pressure walls is not charged with hot-gas exiting from the quench tube at any point but with cold gas, i.e. on the one hand in form of the quench gas Q and on the other hand with already cooled down hot-gas. The charged spaces are separated by a barrier from one another in order to avoid a short-circuit between quench gas and cooled-down hot-gas.

The position of the annular barrier, as seen in the direction of flow of the hot-gas, can be variable.

Figure 3 shows the quench supply unit 6 in more detail. The quench supply unit is an modified quench supply unit as described in Figure 3 and 3a of US-A-4859213. The modification lies in that openings 27 are added through which quench gas can enter the annular space 25. Figure 3 also shows part of the membrane wall 45 of cooled channel 5,7, openings 53 to supply quench gas into the cooled channel 5,7 and part of the supply conduit 9.